A. Cover Sheet *(Attach to front of proposal.)*

1. Specify: [x] agricultural project or [ ] urban project — [ ] individual application or [ ] joint application

2. Proposal title—concise but descriptive: Increased Water Use Efficiency Through Conservation Tillage

3. Principal applicant—organization or affiliation: Steve Temple, Lead Principal Investigator Sustainable Agriculture Farming Systems Project, UC Davis

4. Contact—name, title: Leisa Huyck, Research Manager, Sustainable Agriculture Farming Systems Project

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8. E-mail: lhuyck.@ucdavis.edu

9. Funds requested—dollar amount: $ $536,000

10. Applicant cost share funds pledged—dollar amount: $ $188,065

11. Duration—(month/year to month/year): 06/01 to 06/04

12. State Assembly and Senate districts and Congressional district(s) where the project is to be conducted: 8th State Assembly district, 4th State Senate District, 3rd Congressional District

13. Location and geographic boundaries of the project: Yolo County, California

14. Name and signature of official representing applicant. By signing below, the applicant declares the following:
    - the truthfulness of all representations in the proposal;
    - the individual signing the form is authorized to submit the application on behalf of the applicant;
    - the applicant will comply with contract terms and conditions ~~identified in Section 11 of this PSP.~~ as negotiated between UC & CalFed (2/4)

Steven R. Temple
(printed name of applicant)

2/12/01
(date)

(signature of applicant)

FEB 13 2001

Fay Yee
Contract & Grant Analyst

B. Scope of Work

1. Abstract

Standard tillage practices in California's Central Valley include ten or more energy-intensive and costly operations after harvest, in preparation for a succeeding crop. Fields are tilled without regard to preserving dedicated crop beds or traffic zones. The intensive tillage degrades soil structure and increases soil compaction. This reduces water infiltration into the soil, which, in turn, increases runoff from agricultural areas into natural waterways, resulting in both increased seasonal flooding and decreased groundwater recharge. Sediment- and chemical-laden runoff impairs the quality of water in the Sacramento Delta, impacting both the ecosystem and drinking water.

Conservation tillage (CT) has the potential to increase water use efficiency in agriculture by addressing several of these problems at once. In the short term, CT enhances infiltration by increasing soil surface roughness and decreasing compaction. In the long term, infiltration is enhanced by improvements in soil physical properties such as porosity and aggregate stability. In CT systems which make use of cover crops, soil structure is also improved by the addition of organic matter to the soil, as well as by the development of deep root channels. CT also reduces evapotranspiration at the soil surface. The combined result of these effects in many parts of the country is to increase infiltration to 100 percent and correspondingly decrease runoff to zero. If these kinds of results could be achieved in the Central Valley, the water savings, the reduction in flood control costs, and the reduction in nonpoint source pollution, could all be substantial.

However, CT is currently being used on less than 0.3 % of California farmlands. Discussions with growers in California's Central Valley indicate that there are several reasons for this; primary among these is a lack of information about how to make CT work in furrow irrigated agriculture in California. Very few studies of CT in irrigated agricultural settings have been completed.

We propose to quantify changes in relationships between infiltration, runoff, and soil compaction, with the adoption of conservation tillage, in several tomato-based farming systems in Yolo County. This project is a collaborative effort between several Yolo County growers, the statewide Conservation Tillage Workgroup, and UC Davis' Sustainable Agriculture Farming Systems Project. In the first year, we will work with at least four Yolo County growers to quantify these relationships in their fields, and also measure them on experimental plots at the site of UC Davis' Sustainable Agriculture Farming Systems project. In the second year, we will broaden the study to 6-8 growers' fields, and in the third year will work with at least ten growers.

Community outreach will be accomplished by semi-annual field demonstrations, annual SAFS field days, workshops, annual CT conferences, a website, a listserve, extension bulletins, presentations at meetings, technical publications and popular press articles, newsletters, and other outreach materials. Mailing lists from both the CT workgroup and the SAFS project will be combined, for a total of over 1500 interested agencies and individuals.

2. Statement of critical issues

The high production capacity of California's Sacramento Valley region is attributed to intensive irrigation practices, agrichemical inputs, and intensive tillage, all of which have substantial environmental and social costs. Standard tillage practices include ten or more energy-intensive and costly operations after harvest in preparation for a succeeding crop. Fields are tilled without regard to preserving dedicated crop beds or traffic zones (Carter, 1998; Carter et al., 1991). The intensive tillage, among other consequences, degrades soil structure and increases soil compaction (Franzluebbers et al., 1995; Reicosky, 1998).

This degradation of soil structure reduces water infiltration into the soil. This, in turn, increases runoff from agricultural areas into natural waterways, resulting in seasonal flooding and decreased groundwater recharge. Sediment- and chemical-laden runoff is a major source of nonpoint source pollution, impacting both drinking water and the ecosystem in the Sacramento Delta. Compaction restricts root growth into regions of the soil where moisture and nutrients are sequestered. Consequently, sustained crop production requires greater frequency of irrigation and application of mineral fertilizers. All of these farming operations are highly energy-consumptive and produce CO2 emissions that contribute to the greenhouse effect Post et al., 1990; Pope 1992; Huyck, 1994; Abbey, 1995; Clausnitzer and Singer, 1997; Lal, 1997; USEPA 2000; CARB 2000).

Conservation tillage (CT) could address several of these problems at once. Numerous studies in the Midwest and other parts of the country have shown the benefits of conservation tillage (Franzluebbers et al., 1995; Paustian et al., 1997; Lal et al., 1998). In several paired watershed studies in the Midwest, CT was found to increase infiltration to 100 percent and correspondingly decrease runoff to zero (Fawcetts et al., 1994). Other studies have found CT to improve yields by decreasing compaction, increasing labor and energy efficiency, increasing carbon sequestration and decreasing dust emissions, improving air, soil, and water quality, and providing more and higher-quality habitat for wildlife (Dimmick and Minser, 1988; Seta et al., 1993; Radford et al., 1995; Reeves, 1997; Reicosky, 1998).

CT enhances infiltration through several mechanisms. In the short term, it results in increased surface roughness and decreased compaction. In the long term, it results in the development of improved soil soil physical properties such as porosity and aggregate stability. In CT systems which make use of cover crops, soil structure is also improved by the addition of organic matter to the soil, as well as the development of deep root channels. CT also reduces evapotranspiration at the soil surface. These improvements in water use efficiency have been documented in numerous experiments in many geographic locations (Triplett et al., 1978; Eisenhauer et al., 1984; Edwards et al., 1988; Foy et al., 1989; Fawcett et al.,1994; Ashraf et al., 1999).

However, despite a 300 percent increase in the adoption of conservation tillage in the Midwest and other parts of the country, CT is currently being used on less than 0.3 % of California farmlands (CTIC, 1999; Mitchell et al., 1999). Discussions with growers in California's Central Valley indicate that there are several reasons for this; primary among these is a lack of information about how to make CT work in furrow irrigated agriculture in California (Mitchell et al., 2000). Substantial differences exist between production practices in the Midwest and those in California, due to differences in soils and climates. For example, the lack of freezing and thawing in California has led to the use of deep ripping and tillage to break up hardpans that are not a problem in the Midwest.

In California, recognizing the need for information on CT in irrigated systems, a group of interested growers, researchers, extension specialists, farm advisors, and consultants formed a Conservation Tillage Working Group in 1997. With nurturing from this group, the number of farm fields or experimental plots in which CT is being tried in California rose from one, in the year 1996, to 18, in the year 2000 (Mitchell et al., 2000, and personal communication). The Workgroup currently consists of diverse Cooperative Extension, Agricultural Experiment Station, USDA, private agency, farmer and student membership and has upwards of 60 affiliates. Our 1998 and 2000 conferences, which were held as two back-to-back daylong sessions in Five Points and Davis and which focused on successful conservation tillage systems in other parts of the US, were attended by 500 participants.

Grower/scientist focus groups and discussions at these conferences have identified several areas where information on the potential utility of CT in the Central Valley is deficient and research needs exist. One of the most important areas is that of soil-plant-water relations. Specifically, growers and others would like to know how much potential there is for water conservation in CT systems in California. Several Yolo County growers working with the CT Workgroup have expressed interest in having CT and its potential effects on water conservation demonstrated in their fields (Bruce Rominger, Farmer, personal communication 2001).

The Sustainable Agriculture Farming Systems Project is uniquely positioned to collaborate with the CT Working Group in studying the potential for water conservation in CT systems. The Sustainable Agriculture Farming Systems (SAFS) project was established in 1988 as a 12-year field experiment to study the transition from conventional to low-input and organic farming systems in California's Sacramento Valley. It included four farming-system treatments: four-year rotations under conventional, low-input, and organic management, and a two-year rotation under conventional management. Farmers were involved in every stage of the research and extension: planning and design, execution, and interpretation and dissemination of results. Data were collected on numerous aspects of the different farming systems, including nutrient dynamics, soil physical and biological properties, pest and weed incidence, water relations, economic viability, and others (Clark et al, 1999; Poudel et al., 2000).

Some of the most important findings of the 12-year SAFS project were that cover-cropping in the organic and low-input management had positive long-term effects on soil biological, chemical, and physical properties. These systems showed greater accumulation of plant nutrients and carbon (C), greater biological activity, and reduced root disease severity (Gunapala and Scow, 1998; Clark et al., 1999; Devevre and Horwath 1999; Ferris et al., 1999; Grunwald et al, 2000; Poudel et al., 2000) . They also were found to be economically viable (Livingston, 1995; Klonsky et al., 1997; Clark et al., 1999; Poudel et al., 2000). Most importantly for the purposes of this proposal, soil physical properties were enhanced to the degree that in the cover-cropped systems, simulations using field data on runoff indicated that *less than 15 percent of winter rainfall would be lost as runoff, compared to about 43 percent in the conventional* *systems, with the difference infiltrating and being stored in the soil profile for later use by crop plants* (Joyce et al., submitted).

The 56 plots at the former SAFS site will now be converted to a study of the transition to CT in conventional, low-input, and organic farming systems. As in the SAFS project, data will be collected on many aspects of the farming systems under study, including profitability and soil physical and biological properties. We propose to take advantage of the existence of this study by also quantifying water budgets in the SAFS-CT plots.

Feedback from our conferences indicates that conservation tillage will become more widely adopted throughout the state once successful examples are demonstrated. This proposal to CALFED is a direct result of these evaluations of the needs for information on reduced tillage production systems, and represents a solid integration of broad-based researcher and farmer participants in Yolo County to meet these needs.

3. Nature, scope, and objectives of project

We propose to accomplish two objectives simultaneously—the development of basic information on the water use efficiency of CT systems, and the demonstration of this information in real field situations—by doing the following:

1. In the first year, work with a minimum of four growers in Yolo County who would like to experiment with CT in their fields, to quantify the total water budget for these fields, and collect data on soil compaction.
2. Quantify water budgets and soil compaction in plots at the SAFS-CT site.
3. Conduct workshops on and demonstrations of the results at farmers' fields and at the SAFS-CT site.
4. Over the course of three years, a) identify at least seven more growers in the Yolo County area who would be interested in trying CT, and b) quantify the total water budget in these fields.

It should be noted that this proposal seeks funds only for the portion of the study relating to the relationships between tillage, soil compaction, and water use efficiency. Funds for collection of data on carbon sequestration, energy use, profitability, and other properties of the systems under study at the SAFS-CT site will come from other sources.

4. Methods, Procedures, and Facilities

The CT Workgroup currently relies on modest extension education program support from the University of California's Division of Agriculture and Natural Resources. We also have secured loans or donations of conservation tillage equipment from companies such as John Deere Corporation (Moline, IL), Unverferth Manufacturing, (Kalida, OH), Yetter Manufacturing (Colchester, IL), and Holland Company (Holland, MI). With this equipment and the commitments we have secured from growers in Yolo County, we are uniquely positioned to begin collecting criticallyimportant data on water use efficiency, production costs, energy use, profitability and soil resource quality.

Measurements necessary to quantify the relationships between tillage, water budgets, and soil compaction will be made on sites provided by four growers in Yolo County, and at the SAFS project site.

At growers' fields, the size of plots or fields to be dedicated to the study will be decided by the growers. The basic rotation will be a 2-year one of tomatoes and wheat, starting with tomatoes. Two treatments will be used: the normal growers' practices for the site, and a conservation tillage treatment to be decided upon by consensus of growers and researchers. Adaptive management will be used; as new information is learned, appropriate changes will be made in the treatments. Data collected subsequently will enable us to simulate what would have occurred had the changes not been made.

The SAFS Project is located on 28 acres (38º 32' N, 121º 47' W, 18-m elevation) on the Agronomy Farm of the University of California, Davis. On the main research site, plots of one-third acre each (to allow use of full-scale farm equipment) will be treated with a tillage x farming system factorial design for the conventional, organic, and low-input systems. Four replications of each treatment will be placed in a randomized complete block design. All three farming systems will initially consist of a two-year rotation of tomatoes and wheat, with half the plots starting at each entry point in the rotation. After the first cycle through the rotation, the organic and low-input farming systems will then be rotated into cash crops other than wheat after tomatoes; the choice of crops will be made by the research team after each two-year cycle based on current market and other conditions, as described below.

All farming-system treatments will use "best farmer management practices", to be determined by consensus of the research team, which includes farmers. Farmers participate in every stage of the SAFS research process, including planning and design, execution, and interpretation and dissemination of results. The conventional systems will be managed with practices typical of the surrounding area, which include the use of synthetic fertilizers and pesticides. In the low-input systems, fertilizer and pesticide inputs will be reduced primarily by using legume cover crops to improve soil fertility, and mechanical cultivation for weed management. The organic system will be managed according to the regulations of California Certified Organic Farmers (CCOF, 1995), with no use of synthetic chemical pesticides or fertilizers. Instead, management will include the use of cover crops, composted animal manure, mechanical cultivation, and limited use of CCOF-approved products.

In the first year, the tillage and farming operations will be conducted as shown in Table 1. (A hypothetical budget for these operations is shown in Table 2; please note that water savings are not indicated as the amount of potential savings is unknown as yet.) These operations will be refined as results from studies in the companion area, a smaller 3 ha area which is used to experiment with management practices for application to the main site, suggest improvements. In the companion area, plots of one-third acre each will be used to evaluate different cover crops for use in conservation tillage; evaluate different types of equipment; experiment with different conservation tillage practices such as ridge till, strip till, and others; and learn how to manage conservation tillage in cash crops other than tomatoes and wheat, such as safflower, dry beans, and others commonly grown in the Central Valley.

Data collection: The following measurements will be made in farmers' fields and at the SAFS-CT plots, to quantify the relationships between tillage regime, soil compaction, and water budget:

Soil compaction. Determinations of isoimpedance in the soil profile will be made twice yearly at each plot at each site, using "The Investigator" Soil Compaction Meter.

Water infiltration. Water infiltration rates will be determined using the two-point method as described by Walker and Skogerboe (1987). In this method, the advance and recession phases of irrigation application will be monitored at 30 m and 60 m from the head of each furrow. Infiltration functions will be developed for each furrow using the Kostiakov function: $Z = kta$, where Z is the cumulative depth of infiltrated water, t is the intake opportunity time, and k and a are empirical constants. This equation has been confirmed to be appropriate for furrow irrigation conditions in California by Hanson et al. (1990). To investigate heterogeneity between furrows within a treatment, 3 - 6 furrows will be monitored in each plot.

Infiltration variability will also be measured with a semi-empirical technique developed by Upadhyaya and Raghuwanshi (1999) to measure water infiltration parameters in a furrow irrigated processing tomato crop. Malcolm et al. (1999) successfully used this technique to measure variability in water infiltration rate in a furrow irrigated system. The technique uses a continuous recording ultrasonic flow sensor and specially designed timers to record advance time along the furrow to estimate initial and final infiltration rates based on Horton's infiltration equation. Infiltration studies will be conducted along the trafficked and untrafficked rows using the volume balance and advance time method described by Malcolm et al. (1999) in each of the sub-plots. The initial and final infiltration rates will be obtained in each of the treatment and data will be statistically analyzed to infer the effect of tillage and chemical treatment on these infiltration parameters.

Winter runoff. A simple measurement approach recently developed by Joyce et al. (submitted) will be used to determine surface runoff from plots during the winter in each year of the proposed project. PVC tubes (38.1 cm diameter) will be installed to 1 m depth at the downstream ends of four furrows (2 wheel row and 2 non-wheel row) to collect cumulative runoff from precipitation events. In each measured plot, the width of the runoff area will be defined as the distance between the middle of adjacent plant beds. The length of furrow to be used will be determined by assuming that as much as half of a 2 cm precipitation event would run off. Thus, for a 0.762 m bed spacing a 14m length of furrow was used. The furrow will be blocked and its upstream extent will be diverted to adjacent furrows. Cumulative runoff will be measured after each rainfall event and intermittently for larger events by observing the height of water collected in the catchments.

Precipitation will be recorded by the CIMIS weather station adjacent to the research site. ***Total water use*** will be recorded by flow meters. ***Soil water storage*** will be quantified by neutron hydroprobes. ***Evapotranspiration*** will be measured through a variety of methods, including lysimeters and calculation of reference ET using crop canopy coverage information gathered by digitial infrared camera.

Tillage and farming systems effects on these parameters will be examined using two-way analysis of variance with interaction terms. Mean separation will be performed when appropriate. Temporal trajectories of variables, and relationships between responses and various input or environmental factors, will be analyzed using linear and nonlinear regression, principal components analysis, simulations, and other methods.

5. Schedule

Activities to Complete Objectives	Timing of Activities
Production activities (planting, irrigation, harvesting, etc.)	February- November, 2001-2004
Equipment maintenance	December - February, 2001-2004
Field data collection	Ongoing
Data analysis	Ongoing
Maintenance of website and establishment of listserve	Ongoing
Writing articles, newsletters, and reports	Ongoing
Mailing newsletters, 2 each year	Spring and Fall, 2001-2004
Field days	June, 2002, 2003 and 2004
Field demonstrations	Fall and Spring, 2001-2004
Field tours and presentations	Ongoing

Data will be compiled by the Research Manager into the SAFS-CT database, which is stored on the UC mainframe computer as well as on zip disks, and will be made available to interested parties on request. Results of data analyses will be posted on a website, described in Section C on outreach.

The impacts and success of the project will be assessed formally and informally. The number of participants or attendees will be recorded at all outreach activities (see Section C on Outreach) , to quantify the numbers of people directly exposed to the project. Field day and workshop participants will be asked to complete questionnaires indicating their degree of satisfaction with the content and manner of the information presented. Suggestions on how to make these events more useful will also be requested.

The number of hits on the website will be tabulated, and comments received by the webmaster will be tabulated and summarized regularly. The numbers and kinds of questions and comments on the listserve will likewise be tabulated and summarized regularly. The active participation of extension specialists, farm advisors, and farmers in the project will allow the group to gauge the farming community's opinion of the project and the degree of adoption of CT practices. Ongoing roundtable discussions with growers, as well as conferences and field days, will enable us to continue to develop research strategies to answer growers' questions on CT and water use efficiency.

C. Outreach, Community Involvement, and Information Transfer

The CT Workgroup and the SAFS project *are, in and of themselves,* mechanisms for outreach, community involvement, and information transfer. As stated previously, farmers participate in every phase of SAFS research and extension; they are collaborators in the process, rather than simply a target audience for results. Farmers make up a significant portion of the Workgroup membership. This proposal, then, is being submitted by a collaborative team of farmers and researchers.

The farmer-researcher team that is the SAFS project has, over the past dozen years, developed a highly successful outreach structure. We have a mailing list of over 1500, have hosted several hundred visitors from all parts of the globe, and been featured on national and international television and radio shows. We have developed a self-guided tour, and host annual field days which are attended by between 80-150 growers, farm advisors, exension specialists, resource conservationists, and others. Over a hundred peer-reviewed publications have resulted from the SAFS research, as well as numerous articles in technical and popular media, posters and presentations at professional meetings, extension bulletins, and newsletters. The project has a highly visible profile in both the agricultural community and the research community.

The proposed new study will capitalize on these assets. Results will be extended via field days, workshops, newsletters, a website, extension bulletins, presentations, posters, professional meetings, peer-reviewed publications, technical and popular media articles, local, national and international radio and television interviews, visits by international scholars and officials, and others.

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D. Qualifications of Applicants

1. Resumes (see following pages)

2. External Cooperators (see statements of commitment following resumes)

Two of the farmers who will provide land for this study, Bruce Rominger and Tony Turkovich (see statements of commitment in following pages) are both SAFS team members and CT Workgroup affiliates. Scott Park and Stephen Hiramoto are CT Workgroup affiliates.

Two farm advisors are also part of the SAFS team, Gene Miyao and Tom Kearney. Their resumes are also included in the following pages.

3. Partnerships

This proposal is the result of collaboration between farmers, farm advisors, members of the CT Workgroup, and UCD scientists from the SAFS project (many of whom are also part of the CT Workgroup).

E. Costs and Benefits

1. Detailed Budget:

	Year 1		Year 2		Year 3	
	Cost share	CALFED request	Cost Share	CALFED request	Cost Share	CALFED request
a.Salaries and wages						
10 Co-PI's at 5% time	$30,816		$30,816		$30,816	
Research Manager/ Outreach coordinator		$18,366		$27,549		$36,732
Field operations manager		$36,732		$36,732		$36,732
Graduate student		$18,195		$27,293		$36,390
Hourly laborers (prebaccalaureate students)		$16,800		$25,200		$33,600
b. Fringe benefits	$ 5,239	$15,007	$ 5,239	$21,684	$ 5,239	$28,361
c. Supplies		$15,000		$ 2,500		$ 3,500
d. Equipment	$79,900	$22,900		$20,000		$20,000
e. Travel		$ 2,000		$ 2,000		$ 2,000
SUBTOTAL	$115,955	**$127,000**	$ 36,055	**$162,958**	$36,055	**$197,315**
f.Overhead (10 %)		**$ 12,700**		**$ 16,296**		**$ 19,731**
g. TOTAL	$115,955	**$139,700**	$36,055	**$179,254**	$36,055	**$217,046**

2. Budget Justification

Please note that this proposal seeks funds only for the costs of the portion of the study that will quantify relationships between water use efficiency, tillage, and soil compaction.

a. Salaries and Wages

Ten scientists from UC Davis will donate 5% of their time to this project.

In the first year, a half-time Research Manager/Outreach Coordinator will be needed for day-to-day project management. Duties will include research coordination, employee supervision, supervision of data collection, data analysis and presentation of results, organizing workshops, field tours and field days, newsletter production, and report writing. As the project expands in the second and third years, so too will the amount of time that the Research Manager/Outreach Coordinator will be needed.

A full-time field operations manager will be needed to coordinate farming and tillage operations at all sites, supervise field data collection, keep records of yields and water use, and assist with infiltration measurements.

In the first year, one Research Assistant will be needed to coordinate measurement of infiltration and runoff, soil water storage, and soil compaction, compile and analyze data on water budgets, and develop and use simulation models. The RA will work half-time during the school year and full-time during the summer. As the project expands in the second and third years, so too will the need for RA time.

In the first year, two student assistants will be hired on an hourly basis—half-time during the school year and full-time during the summers—to measure soil water storage and soil compaction at the various sites, and assist with infiltration and runoff data collection. As the project expands, so too will the need for hourly help.

b. Fringe benefits include benefits for Research Manager and Field Operations Manager calculated at 17 percent of salary; $4591/yr fee remission as well as benefits for graduate students calculated at 3 percent of salary; and benefits for the two student assistants calculated at 3 percent of salary. Fringe benefits for PI's, calculated at 17 percent of salary, will be donated.

c. Materials and supplies include seed, transplants, fertilizer, pesticides, water, supplies for runoff and infiltration measurements (PVC pipe, runoff tanks, flow meters), outreach materials, and recordkeeping materials. Neutron hydroprobes will be available through Dr. Jeff Mitchell. Most supplies will be needed in the first year, since that is when the bulk of the runoff catchments will be constructed.

d. The following equipment will be available through donations by the Division of Agriculture and Natural Resources to the Conservation Tillage Workgroup:

Buffalo Rolling Stalk Chopper ($3,400)
Buffalo High Residue Cultivator ($11,500)
Unverferth Ripper Stripper ($14,000)
John Deere 1730 Conservation Tillage Planter ($24,000)
No-till transplanter ($12,000)
Buffalo No-till / Ridge Till Planter ($15,000)

Other farm equipment must be rented:

Truck	$6,000/yr
Tractors	$8,000/yr
Harvester	$4,000/yr

Funds are being sought for two "The Investigator" Soil Compaction Meters with Star Logger and software, at $1450 each, in the first year.

e. Travel will be for outreach purposes to 1 national, 1-2 statewide, and 3-4 regional/county meetings.

3. Benefit Summary and Breakdown

a. *Quantified benefits.* None of the benefits of this project have yet been accurately quantified. The purpose of the project is to collect data that would enable such a quantification of benefits. The project would produce information about a management practice which, if adopted, could provide numerous valuable benefits to both farmers and CALFED. The value of this information could therefore be quite substantial.

We have requested funds from another source to do an ecological-economic cost-benefit analysis of the conversion to conservation tillage in organic, low-input, and conventional farming systems, at both the farm and societal levels. This study, if funded, would take at least three years to complete.

In the meantime, we can only provide rudimentary guesses at the quantitative values of most benefits. We can, for example, develop a hypothetical scenario in which the project leads to adoption of conservation tillage on 75% of the acreage in processing tomatoes in Yolo County. Currently an estimated 67,114 acres are in tomatoes in Yolo County. Simulations using data from the SAFS project show that in a water year of 16 inches of rainfall, approximately 45 percent of precipitation would run off a conventionally tilled field (Joyce et al., submitted). This would result in runoff totaling 37,752 acre-feet of water.

If CT were adopted on 75 % of these fields, for a total of 50,335 acres, and if infiltration then increased to 100 percent, as has been found in to occur under CT in other parts of the country, there would be no runoff from these fields. Instead, 62,919 acre-feet of water would percolate into the soil profile on the 50,335 acres under CT. If cover crops are used as part of the CT system, in this type of water year they would be likely to use approximately 25 % of this water. This would leave 50,335 acre-feet to either remain stored in the soil profile or move into groundwater, depending on the depth of the soil profile and its antecedent moisture status. Storage in the soil profile would benefit both the farmer and CALFED. Groundwater recharge would benefit CALFED. Either way, the water would be saved and flooding reduced. If the value of water in Yolo County is $35/acre-foot (R. Howitt, resource economist, e-mail communication, 2001), this is a benefit of $1,761,725 per year to CALFED. There would also be avoided cost benefits from flood and nonpoint source pollution reduction.

Other quantified benefits would include decreased fuel and fertilizer use (SeeTable 2).

b. *Qualitative description of unquantified benefits.* Conservation tillage has been found to confer numerous benefits to farms and ecosystems all over the world. These include, but are not limited to:

- Water savings due to enhanced infiltration
- Consequent reduction in diversion and increased flow
- Reduced flooding
- Reduced nonproductive ET (a CALFED Quantifiable Objective) due to residue management
- Reduced nonpoint source pollution by sediments, nutrients, and pesticides
- Fuel and energy savings
- Soil quality improvement

- Increased carbon sequestration and decreased CO_2 emissions
- Decreased respirable dust emissions
- Improved wildlife habitat
- Increased farm profitability

Most of these benefits would accrue to both farmers and CALFED, some in the short term and some in the longer term. Those benefits that would accrue to farmers directly would include water savings, fuel savings, profitability, and long-term soil quality improvement. These would also accrue to CALFED. The remaining benefits would accrue mainly to CALFED, but also indirectly and in the long term to farmers.

4. Assessment of costs and benefits

This assessment of costs and benefits is based on the above-mentioned hypothetical scenario in which this three-year research project leads to adoption of CT on 75 % of the 67,114 acres in processing tomatoes in Yolo County (50,335 acres), for a period of ten years. Other assumptions are that the value of water in Yolo County is $35/acre-foot (R. Howitt, resource economist, e-mail communication, 2001), that CT would increase infiltration to 100 percent, that cover crops would use 25 percent of this water in ET, and that the same amount of rainfall, 16 inches, will fall each year, uniformly across the landscape.

Please note that this scenario is offered here only to give some idea of the potential for water conservation in CT systems. These assumptions are based on data collected at several locations, including the SAFS site, and are extremely crude. For example, the percentage of rainfall that would be used by cover crops would vary between cover crops and between years as weather conditions varied; we have observed conditions in which cover crops used over 50 percent of precipitation, in drier years, and conditions in which they used less than 15 percent. In a water year of close to 16 inches, the ET of a vetch cover crop was close to 25 percent of precipitation.

Also, in reality it is unlikely that the full benefits of CT would be seen in the very first year of adoption, since it normally takes time for major changes in soil properties to occur. On the other hand, significant benefits have been shown in several of the CT Workgroup's test plots in only the first year (Mitchell, 2000). It is also unlikely that adoption on 75 % of Yolo County's tomato acreage would take place all at once; on the other hand, CT is also likely to be adopted on acreage devoted to many other crops besides tomatoes, including cotton, safflower, corn, dry beans, and others.

In this assessment, only the costs to CALFED are counted as costs. Labor and equipment donated by PI's, and land and labor donated by farmers, are not counted as costs. Yearly costs of the research project are expressed as one-third of the total cost for three years. Present value is calculated using a six percent discount rate. Present value of costs is calculated as the summation of the values over years 1-3; PV for benefits is calculated as the summation of values over Years 1-10.

Hypothetical Cost-Benefit Assessment

Item	Amount	Units	Quantity	Total	Units	Life (years)	Present Value	Beneficiary
Quantified Costs to CALFED								
Labor (salaries plus benefits)	138,458	$/yr	3	415,374	$	3	1,033,441	
Equipment	20,967	$/yr	3	62,900	$	3	156,494	
Supplies	7,000	$/yr	3	21,000	$	3	52,247	
Travel	2,000	$/yr	3	6,000	$	3	14,928	
Overhead	16,242	$/yr	3	48,726	$	3	121,229	
Subtotal	178,667	$/yr	3	536,000	$	3	1,333,555	CALFED
Quantified Benefits								
Reduce labor	Wheat: 20 Tomatoes: 25-30	$/acre/year	50,335 acres, 10 years	Wheat: 10,067,000 Tomatoes: 13,590,450	$	10	Wheat: 74,093,996 Tomatoes: 100,026,895	Farmers
Reduce fuel consumption	Wheat: 20 Tomatoes: 17	$/acre/year	50,335 acres, 10 years	Wheat: 10,067,000 Tomatoes: 8,556,950	$	10	Wheat: 74,093,996 Tomatoes: 62,979,897	Farmers, society
Reduce fertilizer use in tomatoes	20	$/acre/year	50,335 acres, 10 years	10,067,000	$	10	74,093,996	Farmers, CALFED
Reduce surface water demand	35	$/acre/year	50,335 acres, 10 years	17,617,250	$	10	73,805,350	Farmers, Yolo Co. I.D., CALFED
Subtotal	92	$/acre/year	50,335 acres, 10 years	46,308,200	$	10	459,104,130	
Non-Quantified Benefits								
Decrease diversion from Sacramento River	Unknown	N/a	N/a	N/a	N/a	N/a	N/a	CALFED
Increase flow for Quantifiable Objective	Unknown	N/a	N/a	N/a	N/a	N/a	N/a	CALFED
Reduce nonproductive ET for Quantifiable Objective	Unknown	N/a	N/a	N/a	N/a	N/a	N/a	Farmers, CALFED
Reduce flooding	1	AF/YR	50,335 acres, 10 yrs	503,350	AF	N/a	N/a	Yolo Co., CALFED

Non-quantified benefits								
Reduce nonpoint source	N/a	N/a	N/a	N/a	N/a	N/a	N/a	CALFED

pollution								
Improve soil quality	N/a	N/a	N/a	N/a	N/a	N/a	N/a	Farmers, CALFED,
Increase carbon sequestration	N/a	N/a	N/a	N/a	N/a	N/a	N/a	Farmers, CALFED
Reduce CO2 emissions	N/a	N/a	N/a	N/a	N/a	N/a	N/a	Farmers, CALFED
Reduce respirable dust (PM10) emissions	N/a	N/a	N/a	N/a	N/a	N/a	N/a	All Valley residents, CALFED
Improve wildlife habitat	N/a	N/a	N/a	N/a	N/a	N/a	N/a	Wildlife, CALFED
Increase energy efficiency	N/a	N/a	N/a	N/a	N/a	N/a	N/a	Farmers, CALFED

Table 1: Field Operations

Conventional		Low Input		Organic	
CT	ST	CT	ST	CT	ST
Wheat					
-chop residue (July) -spread/incorporate fertilizer (Oct) -plant Wheat (Nov) -apply herbicide (Feb) -irrigate 2x (Apr/May) -harvest (June)	-chop residue (July) -disc 2x (July) -triplane 2x (Aug) -spread fertilizer (Oct) -list 60” beds (Oct) -plant wheat (Nov) -apply herbicide (Feb) -irrigate 2x (Apr/May) -harvest (June)	-chop residue (July) -spread/incorporate fertilizer (Oct) -plant wheat (Nov) -apply herbicide (Feb) -irrigate 2x (Apr/May) -harvest	-chop residue (July) -disc 2x (July) -triplane 2x (Aug) -spread fertilizer (Oct) -list 60” beds (Oct) -plant wheat (Nov) -apply herbicide (Feb) -irrigate 2x (Apr/May) -harvest (June)	-chop residue (July) -spread/incorporate manure (Oct) -plant wheat (Nov) -irrigate 2x (Apr/May) -harvest (June)	-chop residue (July) -disc 2x (July) -triplane 2x (Aug) -spread manure(Oct) -list 60” beds (Oct) -plant wheat (Nov) -irrigate 2x (Apr/May) -harvest (June)
Tomatoes					
-chop residue (July) -apply fallow herbicide (Dec) -strip till bed centers (Apr) -incorporate preplant herbicide (Apr) -transplant tomatoes -cultivate 3x(May/June) -sidedress fertilizer (May) -irrigate 6-7x -harvest (Aug)	-chop residue (July) -disc 2x (July) -deep rip (July) -disc (Aug) -triplane 2x (Aug) -list beds (Oct) -apply fallow herbicide (Dec) -work beds (Apr) -incorporate preplant herbicide (Apr) -transplant (Apr) -cultivate 3x -sidedress fertilizer (May) -irrigate 6-7x -harvest (Aug)	-chop residue (July) -drill faba bean cover crop (Nov) -apply burn down herbicide to cover crop (Mar) -strip till bed centers (Apr) -incorporate preplant herbicide (Apr) -transplant Tomatoes -cultivate 3x -sidedress fertilizer (May) -irrigate 6-7x -harvest (Aug)	-chop residue (july) -disc 2x (July) -deep rip 2x (July) -disc (Aug) -triplane 2x (Aug) -plant faba bean cover crop (Nov) -chop cover crop (Apr) -disc 2x (Apr) -stubble disc (Apr) -disc (Apr) -triplane 2x (Apr) -list 60”beds (Apr) -incorporate Devrinol (Apr) -Transplant (Apr) -sidedress fertilizer (May) -cultivate 3x -irrigate 6-7x -harvest (Aug)	chop residue (July) -drill faba bean cover crop (Nov) -strip till bed centers (Apr) -transplant Tomatoes -sidedress manure (May) -cultivate 3x -irrigate 6-7x -harvest (Aug)	-chop residue (July) -disc 2x (July) -deep rip (July) -disc (Aug) -Triplane 2x (Aug) -plant faba bean cover crop (Nov) -chop cover crop (march) -disc 2x (Apr) -stubble disc (Apr) -disc (Apr) -triplane 2x (Apr) -spread manure (Apr) -list 60”beds (Apr) -transplant (Apr) -cultivate 3x -irrigate 6-7x -harvest (Aug)

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